LANDSAT REMOTE SENSING:

OBSERVATIONS OF AN APPALACHIAN MOUNTAIN TOP SURFACE COAL

MINING AND RECLAMATION OPERATION

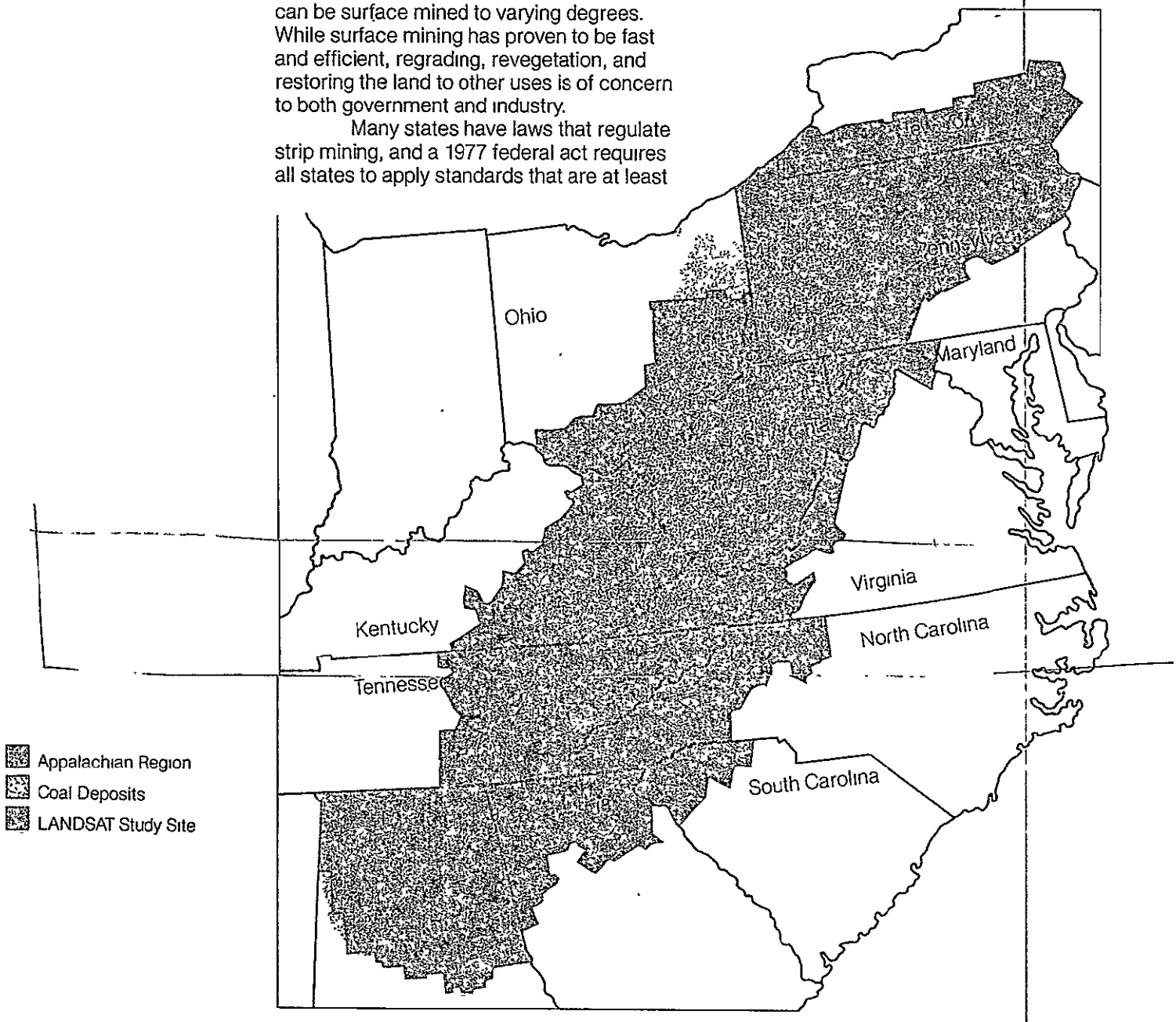# Coal Mining in the Appalachian Region

Over half of our nation's coal is produced by surface or strip mining from seams fairly close to the Earth's surface. In this mining method the coal is exposed by removing and placing to one side the overburden, which is the earth and rock above a coal seam. After the coal is removed, the overburden is re-graded to a desired shape, planted with vegetation or young trees, and the land is restored to productive use

Major deposits of bituminous coal are found in eight states of the Appalachian Region, and two-thirds of these coal seams can be surface mined to varying degrees. While surface mining has proven to be fast and efficient, regrading, revegetation, and restoring the land to other uses is of concern to both government and industry.

Many states have laws that regulate strip mining, and a 1977 federal act requires all states to apply standards that are at least as strict. State agencies presently grant permits to surface mining operators and require bonds to be posted to insure suitable reclamation and revegetation for disrupted areas.

Data from LANDSAT satellites may be used by state agencies to help monitor surface coal mining development and reclamation operations. This brochure describes the application of LANDSAT data to a mountaintop surface mine in eastern Kentucky over a 5-year period from July 1973 to April 1978.

Ohio

Maryland

Virginia

Kentucky

North Carolina

Tennessee

South Carolina

▨ Appalachian Region
▨ Coal Deposits
▨ LANDSAT Study Site

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Appalachian Mountaintop Coal Mining and Reclamation Operations

In recent years in the Appalachian Region there has been a marked shift from contour surface mining of hillsides to area surface mining of mountaintops. Higher lying coal seams are particularly accessible by mountaintop removal methods, and there are substantial coal reserves that are recoverable by these methods.

In the mountaintop removal method of surface mining, the entire overburden is removed down to the coal seam in a series of parallel cuts. The first cut is stripped leaving a high wall and a pit and about a 5-meter-wide barrier layer of the coal seam to support the backfilled overburden to be removed from successive cuts. Overburden from the first cut is transported to a predetermined storage area. The second cut is made parallel to the first cut, and the moved overburden is deposited partly in the first cut space and partly in the storage area. When mining is completed, the mountaintop is covered with a 10- to 20-meter-thick layer of earth and rock that is graded, covered with topsoil, and revegetated. The mountaintop method can create large flat to rolling areas that are generally needed in mountainous regions for the development of airports, industrial sites, and new communities.

Mountain-Top Removal Method

■ Topsoil
■ Overburden
▨ Spoil
■ Coal
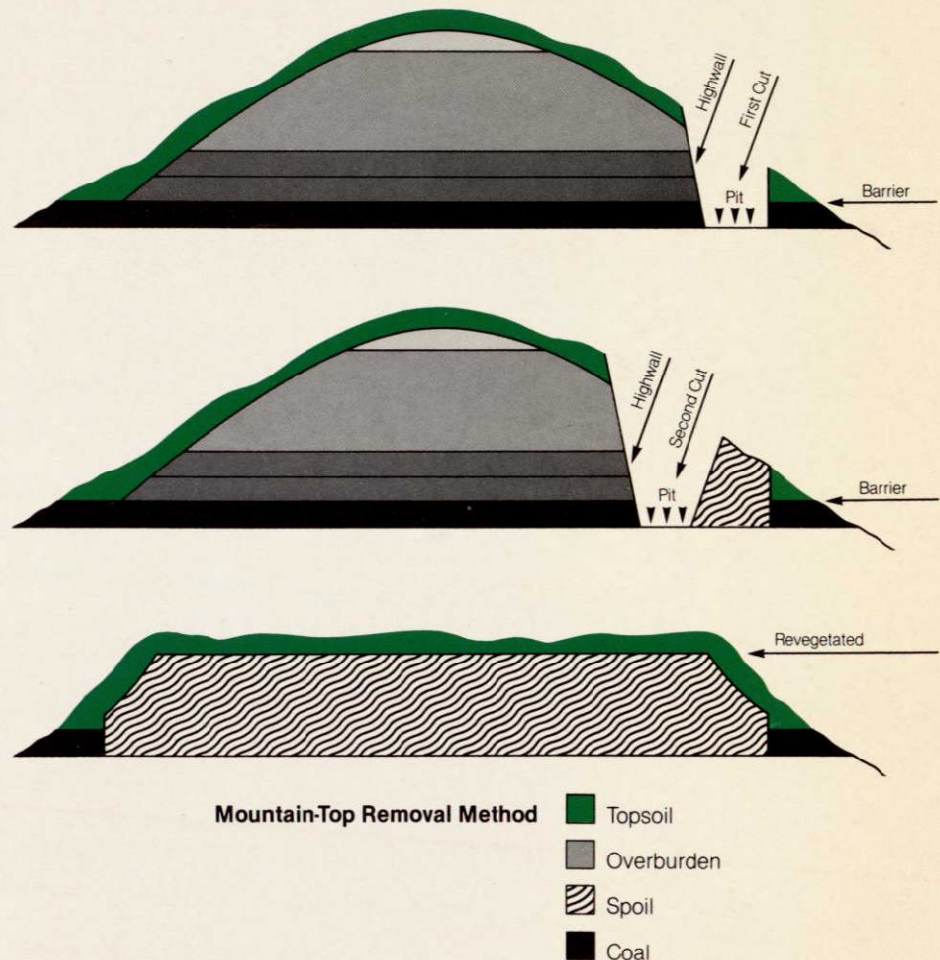
Mountaintop Mine Study Site in Breathitt County, Kentucky

In 1976, the NASA Lewis Research Center and the Kentucky Department of Natural Resources and Environmental Protection, Office of Planning and Research, began a cooperative demonstration project. The objectives were as follows:

1. Develop the application of LANDSAT data for the detection, identification, and classification of various landcover features related to active surface coal mining operations.
2. Evaluate the potential benefits to be derived from the routine application of satellite data for such operations.

Another part of these objectives was to test the possibility of extending the LANDSAT landcover classification process, as calibrated using ground truth for a single surface mine in a given year, to other mines in the vicinity and to earlier and later time periods. In this way, LANDSAT data could be routinely and widely employed in this region of the state with a minimum of corroborating ground data to be collected.

For these reasons, a mountaintop coal mining operation in the rugged, mountainous region of eastern Kentucky, Breathitt County, was selected as the study site. Five years of surface mine development and reclamation from 1973–1978 are reviewed using ground and aerial observations for 1976 to calibrate the LANDSAT data.

9

Landsat

Data Collection

Since 1972 LANDSAT satellites have been collecting data over the Earth's surface. The satellites are in polar, near-circular, Sun-synchronous orbits at an altitude of 920 kilometers. They circle the Earth every 103 minutes (14 times a day) with each successive pass displaced to the west approximately 26° of longitude due to the Earth's rotation. The multispectral scanner (MSS), the primary sensor aboard LANDSAT, provides a continuous series of images of 185-kilometer-wide sections of the Earth's surface. Because of the Earth's rotation under the fixed orbit of the LANDSAT satellite, the entire surface of the Earth can be scanned in 18 days by a single satellite. LANDSATS II and III, now in orbit, combine to provide repetitive 9-day coverage of the Earth.

Data Analysis

The data analyzed in this study were obtained from the MSS. The MSS measures reflected light or radiance in the following wavelength bands: 0.5 to 0.6 micrometer (green), 0.6 to 0.7 micrometer, and 0.7 to 0.8 and 0.8 to 1.1 micrometers (both near infrared). Values of radiance are recorded in each of these four bands for every surface picture element (pixel) scanned, and they comprise a multispectral data set which is the basis for analysis. The four radiance values for each pixel form a characteristic signature for that element. With the use of a digital computer all pixels of a given signature are assigned to a particular grouping or classification. This classification is determined from verified ground landcover areas which comprise computer training sites. For this particular study, three sets of LANDSAT data (July 1973, August 1976, and April 1978) were analyzed and classified into separate landcover classes representative of various stages in surface coal mining operations.

NASA
FORMAL
REPORT

Description of Computer Training Sites

The computer that processes the LANDSAT data must be provided with information from which it can identify the various landcover features of the scene viewed by the satellite. This process effectively trains the computer to recognize these preselected landcover classes representative of surface mining operations. The aerial photographs of the mining area show the location of the various training sites employed.

For simplicity, the final classification was reduced to six landcover classes. Barren areas are separated into two classes consisting of bright limestone areas and dark gray shale areas. The revegetated areas are separated into two broad classes representing greater than 50 percent vegetation cover and less than 50 percent vegetation cover. The undisturbed forest is separated into two classes representing the shady and the sunny side of the native hardwood forests on the hilly terrain. Since the basic ground resolution of each pixel is 1.1 acres, the location and selection of uniform areas of reflectance for use as training sites

for the computer is difficult in small mining areas. The revegetated areas within mine sites are usually small and often limited to about 10 pixels of a definable class. Therefore, for the computer to perform a statistically accurate classification, it is necessary that the total disturbed forest area be about 100 acres.

LOCATION OF TRAINING SITES

1 Barren – Limestone Active
2 Barren – Limestone Haul Road
3 Barren – Limestone Highwall
4 Barren – Shale Spoilbank
5 Barren – Shale-Limestone Mix
6 Revegetated > 50% on Graded Hillside
7 Revegetated < 50% on Graded Hillside
8 Revegetated < 10% on Spoilbank
9 Graded, Seeded Hilltop
10 Graded, Seeded Slope
11 Water Sediment Pond
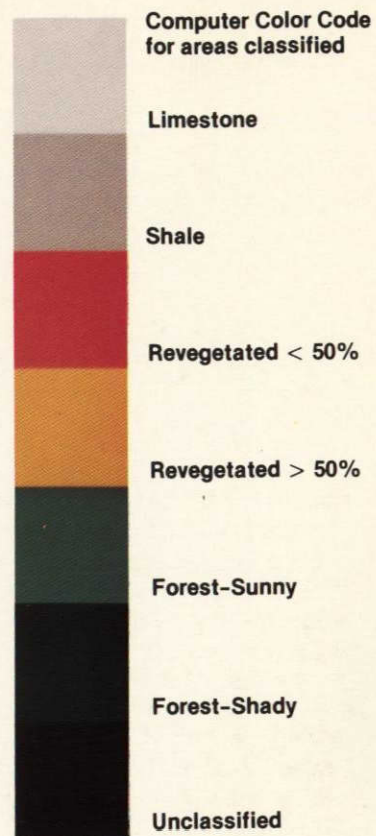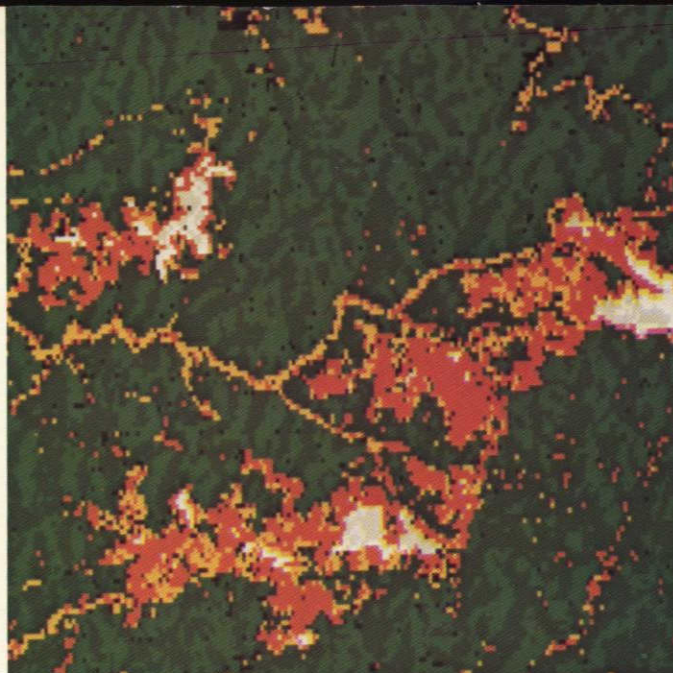12 Forest – Sunny
13 Forest – Shady
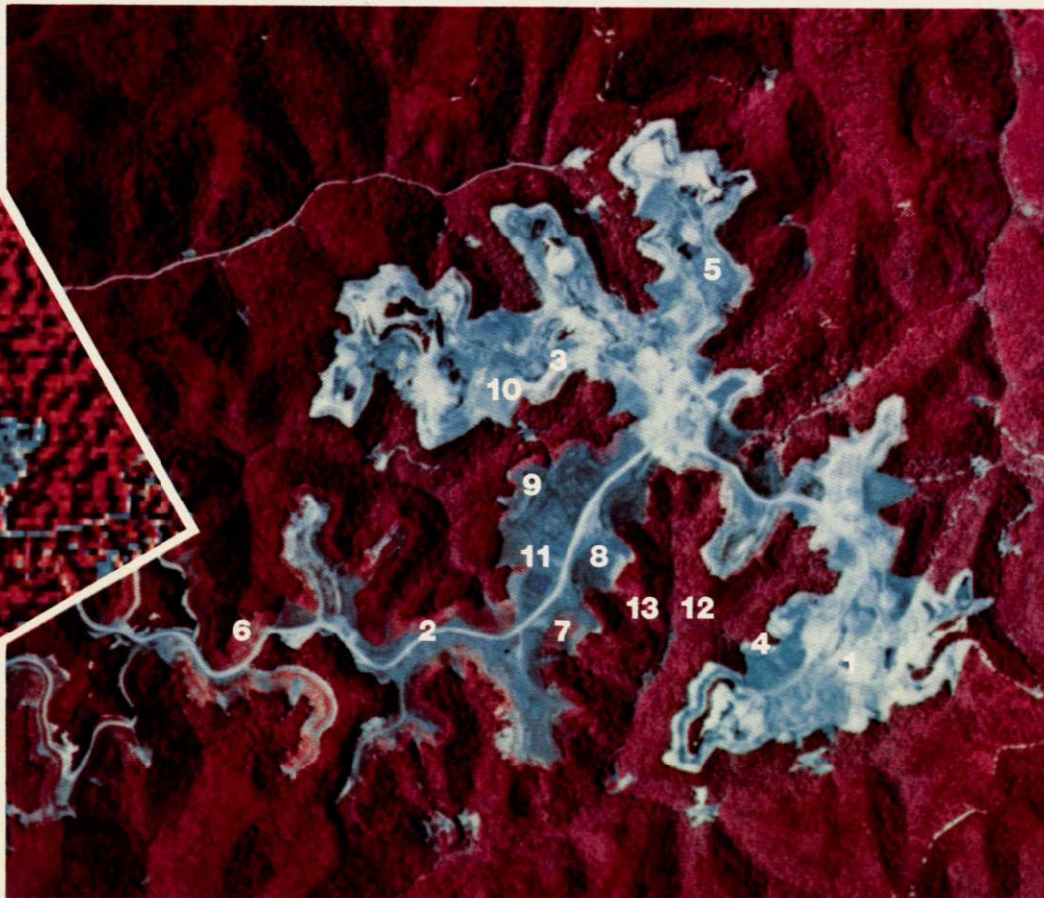
Color infrared aerial photograph of Eastern Kentucky mountaintop surface coal mine taken in June, 1976 showing training sites for computer classification of LANDSAT multispectral scanner data.
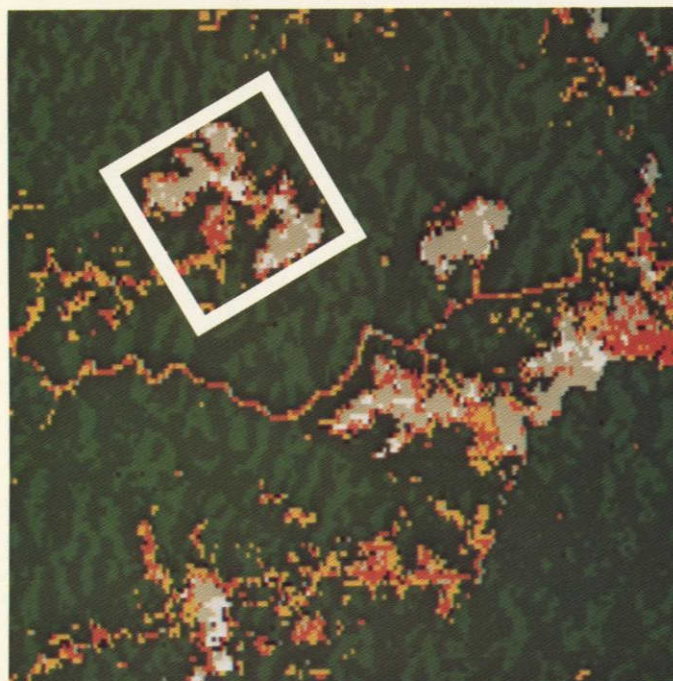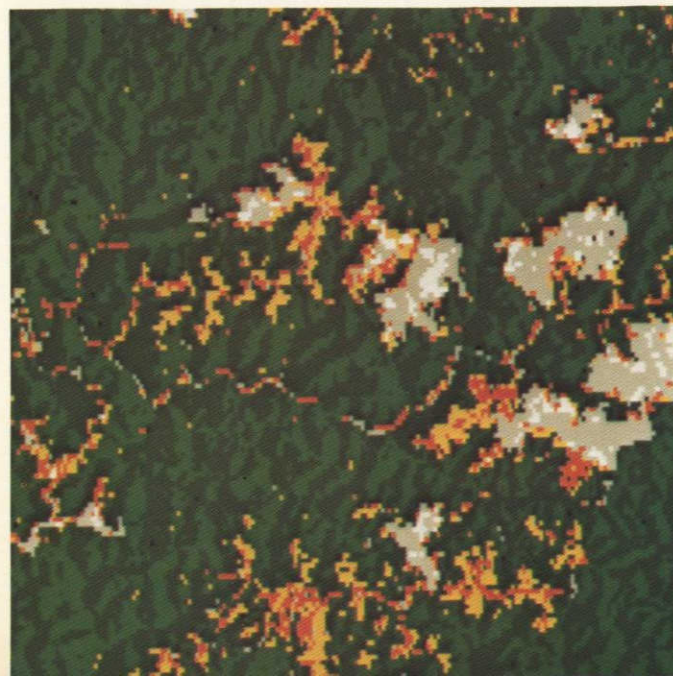
Computer Analyzed
LANDSAT Coverage

July 12, 1973

August 19, 1976

April 14, 1978

**Computer Color Code
for areas classified**

Limestone

Shale

Revegetated < 50%

Revegetated > 50%

Forest–Sunny

Forest–Shady

Unclassified

Progressive Changes in Surface Mine Operations

The potential benefits of using LANDSAT remote sensing techniques to observe progressive changes in mining and reclamation operations are shown in the computer analyzed sequence for the 5-year period. The computer-identified landcover classes are based on the spectral signatures developed by correlation with aerial and ground observation during August 1976. The general color coding used consists of white and gray for recently disrupted barren areas, orange and yellow for increasingly revegetated areas, and green and dark green for sunny and shaded forested areas. Black pixels represent unclassified areas.

The gradual enlargement of newly mined areas and reclamation of older mined areas may be readily discerned. Since revegetated areas begin as a mixture of barren and vegetation classes, the computer may confuse the early stages of reclamation with sparse natural vegetation on spoil banks or marginally reclaimed areas. However, as vegetation becomes established, reclaimed areas of greater than 50 percent vegetation are more accurately discerned.

Since most of the forest is hardwood, the stands of trees are frequently harvested prior to the start of surface mining operations. Therefore, areas that are indicated as partially revegetated in the LANDSAT classification prior to the development of the surface mine may indicate the presence of logging operations. Several such areas are indicated as partially vegetative in the 1973 classified scene which are subsequently classified as shale or limestone as the surface mine is developed.

The limestone haul roads are clearly visible in the classified data but show up as partially vegetative classes. This is a consequence of the 80-meter resolution of the LANDSAT MSS, which records an average mixed radiance of the narrow limestone road and the surrounding forest within a pixel and results in the assignment by the computer as a partially revegetated class.

In regard to the accuracy of the computer classification of the groupings of pixels in the scenes, the best estimate can be made from the August 1976 classification by comparing with June 1976 aerial photography and associated ground surveys. Estimates for the August 1976 scene are 90 percent accurate for identifying forested and barren areas and 60 percent accurate for identifying the partially revegetated areas.

The accuracy of computer classification of landcover is presently limited by the 80-meter spatial resolution of the LANDSAT multispectral scanner system and by the relatively small areas associated with the progressive surface mining activity.

Other LANDSAT satellites that will become available in the near future will operate with both the MSS with 80-meter resolution and a thematic mapper scanner with 30-meter resolution. With the thematic mapper most of the spatial resolution limits to land use classification should be improved.
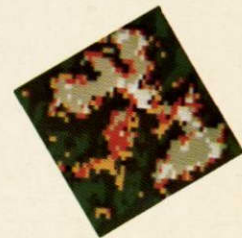
Summary

The potential benefits of using LANDSAT remote sensing data by state agencies as an aide in monitoring surface coal mining operations have been reviewed. A mountaintop surface mine in eastern Kentucky was surveyed over a 5-year period (1973–1978) using satellite multispectral scanner data that were classified by computer analyses. The analyses were guided by aerial photography and by ground surveys of the surface mines procured in 1976. The application of the LANDSAT data indicates the following:

1. Computer classification of the various landcover categories provides information for monitoring the progress of surface mining and reclamation operations.
2. Successive yearly changes in barren and revegetated areas may be qualitatively assessed for surface mines of 100 acres or more of disrupted area.
3. Barren areas consisting of limestone and shale mixtures may be recognized, and revegetated areas in various stages of growth may be identified against the hilly forest background.

LANDSAT SOURCES OF ASSISTANCE

NASA Regional Applications Program

The LANDSAT Remote Sensing Technology Program is administered by the NASA Office of Space and Terrestrial Applications in Washington, D.C. The Technology Transfer Division of this office supports liaison activities between NASA and potential users of LANDSAT data as part of a Regional Remote Sensing Applications Program. Under this program user training and demonstration capabilities are available at three NASA Regional Centers. Each Regional Center is responsible for the states in its geographic area. Also, each Regional Center is prepared to answer questions from state and local agencies about LANDSAT technology.

U. S. Geological Survey

The Geological Survey of the U. S. Department of the Interior maintains a data center for storing, reproducing, and distributing LANDSAT data, other satellite imagery, and aerial photographs. It also supports a staff engaged in training at a computer complex and photographic laboratory in Sioux Falls, South Dakota. The Geological Survey also maintains several National Cartographic Information Centers (NCIC) across the country that provide access to a browse file of LANDSAT scenes so that the user may judge the suitability of the scenes for clarity and cloudcover prior to ordering the imagery.

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